ONTARIO DEPARTMENT OF EDUCATION

CURRICULUM S-27B

# ELEMENTS OF ELECTRICAL TECHNOLOGY

GRADES 11 AND 12

1968

# CONTENTS

FOREWORD 2

AIMS AND OBJECTIVES 2

SAFETY 3

ORGANIZATION 3

DIVISION 1: Theory and Test 4

DIVISION 2: Electronics 6

DIVISION 3: Installation and Maintenance 8

LABORATORY SKILLS AND TECHNIQUES 10

# FOREWORD

An integrated technical course is one in which two or more disciplines that have common or complementary content are combined into one technology. This course outline in Elements of Electrical Technology represents an integration of subject content in the electrical field. The outline consists of three Divisions: Theory and Test, Electronics, and Installation and Maintenance. It is intended for use in Grades 11 and 12.

At the secondary school level, we are concerned with fundamentals rather than the treatment in depth which characterizes the tertiary levels of education. An integrated approach is desirable because students understand basic principles best if they are able to relate them to several subjects. The relation of various technical subjects to mathematics, science, English and history should be stressed repeatedly. In this way the technical subjects become effective educational vehicles as well as a means of learning skills.

Since the course is a two-year entity, the teachers must decide the extent to which any unit will be studied in either Grade 11 or Grade 12. Although the arrangement of the outline is logical, it is not chronological: it is an analysis of subject content, not a synthesis. *No attempt has been made to arrange the topics in a teaching sequence nor has any attempt been made to integrate the topics of the three divisions*: these tasks are reserved for the professional teacher. The need for frequent consultation among the participating teachers is imperative. If possible, one or two periods per week should be set aside so that course construction, lesson planning, and evaluation can be pursued as a team effort.

The course outline was prepared on the understanding that a total of six hundred hours was available for implementation: of this time allotment, about thirty-five per cent should be devoted to Division 1, forty per cent to Division 2, and twenty-five per cent to Division 3. Teachers may alter these ratios somewhat, and may omit optional topics (marked “O”) in favour of other material.

Approximately sixty per cent of the available time should be devoted to student activity that reinforces theoretical aspects. The teacher may, however, increase this ratio by developing individualized, imaginative methods. The inductive, directed-discovery approach should be implemented as frequently as possible.

Since Division 1 forms a common core for the entire course, any participating teacher may present any portion of it. In order to avoid duplication of effort, teachers must collaborate on a regular basis: the vertical or chronological sequence is the responsibility of the instructors who are presenting the course.

Students should feel that they are taking *one* technical subject. This may be accomplished by innumerable arrangements and varieties of presentation. To illustrate the manner in which a given topic relates to sections in all divisions, one might consider Transformers (Section 17.1). Without any selection as to sequence or to depth of treatment, Transformers can be related to the following:

| | |
|---|---|
| 11.1 | Direct current |
| 11.2 | Magnetism |
| 13.1 | D.C. generators |
| 15.1 | Alternating current |
| 15.2 | Inductance |
| 16.1 | Three-phase fundamentals |
| 17.3 | Three-phase induction motors |
| 21.5 | Transformers (electronic components) |
| 23.1 | Power supplies |
| 23.2 | Circuits using amplifying devices |
| 24.1 | Audio amplifiers |
| 24.3 | Radio transmitters and receivers |
| 34.4 | Transformer installations |
| 34.5 | Transformer protection |
| 34.6 | Transformer testing and maintenance |
| 35.5 | Reduced voltage starters |

This list illustrates the fact that the course outline offers an organization of content, but does not inhibit teachers from developing a coherent sequence related to the particular requirements of their classes and the facilities at hand.

## AIMS AND OBJECTIVES

The primary aims of technical education are identical with those of education as a whole: developing each student’s personality and capabilities, and giving him constructive attitudes towards himself and society.

Any technical curriculum should be such that (1) it provides a sound educational base from which further education or training may proceed, (2) it prepares for employment by the development of basic technical skills.

The specific objectives of Elements of Electrical Technology are to develop the student’s ability to:

- Comprehend the impact of electrical technology upon an industrialized society
- Define his vocational goals within the electrical and electronics industry
- Understand the principles upon which the operation of electrical and electronic apparatus depends
- Use simple mathematics pertinent to electrical theory, and interpret such mathematical expressions in terms of physical realities
- Prepare coherent, orderly laboratory reports
- Do independent research for technical information from various sources
- Appreciate and practise sound safety procedures
- Assume responsibility, and work independently of supervision
- Interpret service information and use it intelligently
- Relate schematic diagrams to actual circuitry
- Select and utilize a wide variety of electrical measuring equipment
- Diagnose faults, and service a diversity of electrical equipment, working from first principles.

## SAFETY

The responsibility for safety consciousness rests with the teachers of Elements of Electrical Technology. Not only should they describe potential dangers and possible unsound procedures clearly before any practical student activities, but they must also lead students to "think safety" at all times.

Representatives of recognized industrial safety organizations should be invited to inspect the technical department shops in order to assess equipment and routines. In addition, these representatives might be asked to speak to students and/or teachers on modern safety practice.

# ORGANIZATION

## DIVISION 1: THEORY AND TEST

**Units** 1.1 Fundamentals of Electricity and Magnetism
1.2 Electrical Measurement
1.3 D.C. Machines
1.4 D.C. Motor Controls
1.5 Single-phase Circuits
1.6 Three-phase Circuits
1.7 A.C. Machines

## DIVISION 2: ELECTRONICS

**Units** 2.1 Standard Electronic Components
2.2 Electron Devices
2.3 Basic Electronic Circuits
2.4 Electronic Systems
2.5 Test Equipment
2.6 Servicing and Test Procedures
2.7 Construction Methods and Techniques

## DIVISION 3: INSTALLATION AND MAINTENANCE

**Units** 3.1 Trade Requirements
3.2 Ontario Electrical Code
3.3 Electrical Wiring Systems
3.4 Distribution Systems
3.5 A.C. Motor Controls
3.6 Electrical Maintenance

# DIVISION 1: THEORY AND TEST

## INTRODUCTION

This division should be considered basic to the entire course. The concepts and principles relating to circuits, components, and machines will constantly serve as a foundation for the study of Divisions 2 and 3. This is not to imply that Division 1 should be taught as a whole, but rather to indicate that portions of it should be introduced prior to related studies in other divisions. The teacher must determine the exact chronological sequence of the material in a manner which he considers to be most viable in an educational sense. This arrangement of content should, as far as possible, involve student activities that can be described as "learning experiences". To achieve this, a program less rigidly structured than the traditional should be considered.

The emphasis in Division 1 should, for the most part, be on underlying principles, not on hardware or its manipulation. The studies can be used to realize many of the objectives listed in this publication. The related science and mathematics should be integrated with the electrical theory, as the latter is studied within the shop or laboratory. This integration will be furthered by discussions among technical subject teachers and those responsible for instruction in English, science, and mathematics.

The discipline of Elements of Electrical Technology relates to the control of the electron; therefore, a description of the properties of the electron is a logical beginning. All electrical phenomena may be interpreted in light of an understanding of electron behaviour. Students should become able to anticipate this behaviour under various conditions, i.e., hypothesize to a limited extent.

Many illustrations from industrial equipment and practices will serve to emphasize the need for a broad background in the electrical field. The teachers can reinforce this point by arranging plant tours, and by the use of good films and other reference material. In addition, the students' opportunities for education at the tertiary levels will be enhanced by the comprehension of fundamentals. In this regard, the subject content of Division 1 provides a vehicle for formative learning and experience.

### UNIT 1.1

### FUNDAMENTALS OF ELECTRICITY AND MAGNETISM

**Direct Current**

Electron Theory
Electrical Charges
Methods of Producing EMF
Electrical Circuits
Electrical Conductors and Insulators
Electrical Power and Energy

**Magnetism**

Theory of Magnetism
Magnetic Fields
Magnetic Properties of Materials
Electromagnetism
Magnetic Circuits

### UNIT 1.2

### ELECTRICAL MEASUREMENT

**D.C. Instruments**

D'Arsonval Movement
Instrument Reading
Series ohmmeter
Insulation Tester

**A.C. Instruments**

Rectifier Instruments
Multimeters
Moving Iron Instruments (O)
Electrodynamometer (O)

**Electrical Bridges**

Wheatstone bridge
Introduction to a.c. bridges

### UNIT 1.3

### D.C. MACHINES

**D.C. Generators**

Electromagnetic Induction
Single Loop Generator
Construction and Internal Connections
Self-excitation
Operating Characteristics
Commutation

**D.C. Motors**

Motor Principle
Construction and Internal Connections
CEMF
Operating Characteristics
Efficiency of D.C. Machines
Dynamic and Regenerative Braking (O)

## UNIT 1.4

## D.C. MOTOR CONTROLS

**Variable Voltage Speed Controls**
Control by Armature Voltage

**D.C. Constant Potential Controls**
Principle of Operation
Control Devices and Circuits

**Closed-Loop Regulating Systems**
Theory of Operation
Methods of Obtaining Feedback Signal
Amplification of Feedback Signal
Error Correction

## UNIT 1.5

## SINGLE-PHASE CIRCUITS

**Alternating Current**
Scalar and Vector Quantities
Sine Waves
Phase Relationships
Non-sinusoidal Waveforms
A.C. power: Purely Resistive Circuit

**Inductance**
Self-inductance
Current in Circuits containing Pure Inductance Only
Current in L-R Circuits
Inductive Reactance
Power Factor
Low Frequency Inductors
Series and Parallel Connections
Impedance

**Capacitance**
Elementary Capacitor
Construction and Characteristics of Commercial Capacitors
Series and Parallel Connections
Time Constant
Capacitive Reactance
Impedance of a C-R Circuit

**Series and Parallel Circuits**
L-C-R Series Circuit
Series Resonance
L-C-R Parallel Circuit
Parallel Resonance
Power in L-C-R Circuits

## UNIT 1.6

## THREE-PHASE CIRCUITS

**Three-phase Fundamentals**
Three-phase Waveforms
Star and Delta Connections
Three-phase Power

**Polyphase Power Rectification**
Three-phase Rectifier Systems
Six-phase Rectifier Systems (O)

## UNIT 1.7

## A.C. MACHINES

**Iron-Core Transformers**
Mutual Induction
Construction and Function of Parts
Turn and Voltage Ratios
Operation under load
Current Ratios
Vector Diagram Analysis (O)
Losses
Efficiency and Ratings
Single-phase Connections
Auto-transformers
Instrument Transformers (O)
Polyphase Connections
Open-delta (O)

**Alternators**
Single-phase Alternators—Construction and Operation
Three-phase Alternators—Parts and Construction
Three-phase Connections
Losses, Temperature Rise (O)
Efficiency, Ratings (O)
Voltage Regulation (O)
Synchronization

**Three-phase Induction Motors**
Principle of Operation
Construction of Squirrel-Cage Induction Motor
Operating Characteristics of Squirrel-Cage Motors
Factors Affecting Speed and Regulation
Wound-Rotor Motor

**Single-phase Motors**
Survey of Single-phase Motors
Series
Split-phase and Capacitor-start Induction Motors
Shaded Pole
Repulsion-induction (O)

**Synchronous Motors (O)**

Construction
Principle of Operation
Operating Characteristics

# DIVISION 2: ELECTRONICS

## INTRODUCTION

The material in Division 2 falls into two classifications: recommended and optional. The recommended portions are considered of a nature fundamental to the teaching of any course in electronics while the optional items indicate possible directions which a class or student might pursue.

Note that the material is in no way an outline of a course of study ready to be used by the teacher. It has intentionally been compiled in a manner which groups topics by generic type without regard to sequence of teaching. With this in mind the units have been assembled, each comprising sections and topics of a similar type, such as standard electronic components, and electron devices. This method provides a satisfactory overview and allows for a simple method of defining of subject depth. At the same time, being open-ended, each unit can sustain additions or deletions from time to time without the overall logical structure being affected. Within this framework the teacher's traditional freedom to plan his own course of study is not impaired: the onus is on him to select material, organize the sequence, and plan lessons and projects.

There has been some criticism in the past about "communications-oriented" courses of study. As a result there has been a conscious effort on the part of the committee to provide a wide enough choice in the optional areas that a teacher can, if he so desires, largely avoid the communications field.

At the same time the committee felt strongly that our task is to teach the fundamentals of electronics and that the areas of "specialization" such as "industrial electronics", "data processing electronics" are simply descriptions of the fields from which meaningful applications of these fundamentals can be drawn. This raises the question of interest and motivation and here a strong argument in favour of the so-called communications field appears. The average student is familiar with and interested in such items as television, high fidelity, guitar amplifiers, portable and car radios; this familiarity makes applications of fundamentals in these areas meaningful. This is not to suggest that process control applications or a data handling are unsuitable or undesirable topics; however, the teacher must overcome the lack of the pre-conditioning motivation that exists in the communications field.

Although vacuum and gaseous tubes are included in this division, the time allotted to these areas should be less than that devoted to semiconductors. With the advent of integrated circuits and computers, students should be given the opportunity to think in terms of electronic systems, and come to appreciate a "systems approach" analysis.

### UNIT 2.1

### STANDARD ELECTRONIC COMPONENTS

**Magnetic Relays**

Electromechanical Features
Commercial Types
Typical Applications

**Resistors**

Types, Applications

**Inductors**

Types, Applications

**Capacitors**

Types, Applications

**Transformers (Electronic Components)**

Iron-core
Air-core
Ferrite-core

### UNIT 2.2

### ELECTRON DEVICES

**Vacuum and Gaseous Tubes**

Vacuum Diodes
Vacuum Triodes
Vacuum Pentodes
Multi-purpose Vacuum Tubes
Light-sensitive Tubes
Cathode Ray Tube
Radiation Detectors (O)
Readout Devices (O)

**Semiconductors**

Basic Physics of Semiconductor Materials
Diodes
Transistors
Other Non-linear Devices (O)

### UNIT 2.3

### BASIC ELECTRONIC CIRCUITS

**Circuits Using Diodes**

Power Supplies
Clippers, Clamps and Limiters (O)
Voltage Regulation
Demodulating Circuits

**Circuits Using Amplifying Devices**

Vacuum tube voltage amplifiers
Vacuum tube power amplifiers
Solid state amplifiers
R.F. amplifiers
Oscillators
S.C.R. circuits
Pulse circuitry (O)
Logic circuits (O)

## UNIT 2.4

### ELECTRONIC SYSTEMS

NOTE: Select any 3 sections

**Audio Amplifiers**

Electrical transducer
Audio amplification
High fidelity

**Industrial Control**

Photoelectric control
Motor control
Regulation: generator voltage and current
Welding control (O)
R.F. heating control (O)

**Radio Transmitters and Receivers**

Amplitude modulation
Frequency modulation

**Digital Computers**

Binary notation
Digital electronic systems
Block diagram of basic computer

**Television**

TV receivers: block diagram
TV systems: closed circuit, broadcast

## UNIT 2.5

### TEST EQUIPMENT

**Conventional Meters (as used in Electronics)**

D.C. meters
A.C. meters
The V.O.M.

**The Electronic Voltmeter**

Voltmeter Function
Ohmmeter Function

**The Cathode Ray Oscilloscope**

Theory of Operation
Applications
Adjustment and Use

**Signal Generators**

Audio Frequency
Radio Frequency
Other Types (O)

**Utilization of Test Equipment**

Exercise of Proper Care
Selection for Specific Use

## UNIT 2.6

### SERVICING AND TEST PROCEDURES

**Identifying the Fault**

Symptoms
Intermittents
Analysis of Symptoms

**Isolating the Defective Stage**

Signal Substitution Method
Bracketing Method
Measurement

**Isolating the Defective Component**

Observation
Testing Components
Measurement of V, R and I

**Repair of the Fault**

Component Substitution
Selection Replacement
Installation of Replacement

**Complex Systems**

Isolation of Defective Section
Isolation of Defective Stage

**Routine Maintenance**

Reasons for Routine Maintenance
Methods of Preventive Maintenance

**Alignment and Calibration**

Necessity of Alignment and Calibration of Instrument
Alignment and Calibration Procedure

## UNIT 2.7

### CONSTRUCTION METHODS AND TECHNIQUES

**Development Methods Using Conventional Techniques**

Breadboard Construction
Metal Chassis Working
Placement of Components
Wiring Methods

**Printed or Etched Wiring**

Copper Clad Board
Plain Board

**Modular Circuits**

Turrets (O)
Packaged Circuits
Plug-in Circuit Boards

**Miniaturization**

Discrete Components
Thin Film Techniques
Integrated Circuits

# DIVISION 3: INSTALLATION AND MAINTENANCE

## INTRODUCTION

In many schools this division of Elements of Electrical Technology will be taught in the same room as Division 1. In such cases, one teacher may teach both divisions and the correlation of the material will blend automatically; however, where separate areas exist for Theory and Test, and Installation and Maintenance it is imperative that topic sequence be established by the participating teachers.

This division is very practical in nature, approximately sixty-five per cent of the class time being devoted to student activity. The teacher may increase this ratio through original and imaginative use of available hardware. Every opportunity should be given the students to develop their own circuitry as solutions to various given problems.

Since some of the material may be difficult to present within the electrical shop, field trips are recommended. In this way the student may become familiar with various installation techniques and practices.

In all projects the circuitry and installation procedures should adhere strictly to the Ontario Electrical Code Regulations. These regulations play a substantial role in installation and maintenance, their interpretation and application presenting a challenge to the student. It is recommended, therefore, that open book examinations be used as a means of testing the student's ability to locate and interpret relevant portions of the code.

Throughout the course the instructors should introduce electrical drafting exercises which integrate with the regular course material. The drafting projects should conform to good design practice.

### UNIT 3.1

### TRADE REQUIREMENTS

**Apprenticeship**

Educational Requirements
Apprenticeship Act

**Social Structure of the Trade**

Labour Orangization
Organizational Pattern
Working Conditions

**External Jurisdication**

Licensing - Municipal, Provincial
Inspection - Municipal, Provincial

### UNIT 3.2

### ONTARIO ELECTRICAL CODE

**Content and Use**

Object and Scope
Safety
Approval Procedures
Legal Status
Utilization

### UNIT 3.3

### ELECTRICAL WIRING SYSTEMS

**Non-metallic Sheathed Cable**

Regulations
Installation Procedures

**Armoured and Aluminum-sheathed Cable**

Regulations
Installation Procedures
Testing Armoured Cable
Aluminum-sheathed Cable

**Electric Metallic Tubing**

Regulations
E.M.T. Fittings
E.M.T. Installation

**Rigid Conduit**

Regulations
Preparation
Installation

**Special Raceway Systems (O)**

Types: Surface, Underfloor
Installation Procedures

**Signal**

Intercommunication System

### UNIT 3.4

### DISTRIBUTION SYSTEMS

**Single Occupancy Services**

Regulations
Single-phase, Three-wire System
Service Calculations
Service Materials
Grounding
Service Installation

**Multi-occupancy Services**

Regulations
Layouts
Service Entrance Materials
Installation

**Three-phase Services**

Types
Regulations
Metering
Calculations and Materials
Installation

**Transformer Installations**

Categories
Parts, Nomenclature, and Identification
Name-plate Information
Transformer Bank Connection

**Transformer Protection (O)**

Primary and Secondary Fusing
High-voltage Protection
Lightning Protection

**Transformer Testing and Maintenance (O)**

Inspection Prior to Installation
Fluid Maintenance
Leaks
Moisture Removal

## UNIT 3.5

## A.C. MOTOR CONTROLS

**Elements of a Motor Control System**

Regulations and Definitions
Disconnecting Means
Overcurrent Protection
Contactor
Overload Protection
Considerations in the Choice of Control System
Combination Starter

**Conductors and Protective Devices**

Regulations
Fuses vs. Time Delay Fuses
Circuit Breakers: Types and Sizes
Calculations for Motor Grouping

**Manual Starting Switches**

Single-phase, Across-the-line Motor Starting Switches
Single-phase Reversing Drum Controllers
Three-phase Drum Reversing Controllers

**Magnetic Across-the-Line Starters**

Internal Circuit
Related Control Devices
Reversing Magnetic Starters

**Reduced-Voltage Starters**

Purpose
Features
Automatic Compensator
Wye-delta Starters

## UNIT 3.6

## ELECTRICAL MAINTENANCE

**Diagnosis of Faulty Circuits**

Circuit Analysis and Tests
Test Equipment Requirements

**Industrial Equipment**

Controls
Motors
Preventive Maintenance

**Domestic Appliances**

Any two of:
Water Heaters
Ranges
Dryers
Oil Burners

# LABORATORY SKILLS AND TECHNIQUES

The graduate of Elements of Electrical Technology should be able to perform laboratory experiments accurately and report them clearly.

Before the student reaches this stage, however, he will need careful and explicit instruction in the experimental method. He will need to watch demonstrations of relevant procedures and skills and he should study examples of good report writing and organization.

An important part of the Elements of Electrical Technology course is the preparation of technical articles. The student will probably consult the teacher before choosing his topics, but from that point on he will work independently, do individual research, and supply at least three or four reference sources. This is a good time for the teacher to emphasize the importance of language skills in technical subjects: he may ask a member of the English Department to judge the composition of the essays, with emphasis on clarity rather than style.